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TECHNICAL PROBLEMS ENCOUNTERED
WITH THE LALA-1 FLYING LABORATORY

J. Swidzinski

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The ambitious program for the development of a modern agricultural support aircraft with a high lifting capacity which will become a worthy successor to the An-2 in the last quarter of the 20th century confronted the Polish aircraft industry with many difficult organizational and technical problems. The rapid development of agricultural support aircraft services in all CMEA countries, in particular in the Soviet Union, imposes stringent requirements on an aircraft in regard to its reliability, efficiency and economic feasibility. A considerable qualitative leap forward must be made in this field to meet this difficult task. It is not surprising that work on the design of a new agricultural support aircraft occasionally proceeds along the lines of unconventional solutions, for example in the selection of hitherto unutilized propulsion systems, new systems of agricultural equipment, etc. Research and experiments must be conducted to avoid surprises and to reduce to a minimum the risk entailed in such a project. A large portion of this work was entrusted to the Aircraft Institute. Among other problems, the Institute was confronted with the task of investigating in practice the effect of jet propulsion on the properties and characteristics of agricultural support aircraft. Appropriate research equipment had to be elaborated and constructed for this purpose. Many versions of such equipment were discussed, beginning with stationary stands through equipment based on vehicles moving on ground on wheels

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and rails and ending with aircraft equipment.

Aircraft equipment was acknowledged to be most appropriate for meeting the stipulated requirements since it allows to conduct investigations in the most complex manner under conditions which most nearly approach real conditions under which new agricultural support aircraft operate. It also became evident that this aircraft equipment can be elaborated in a rather short time at a relatively moderate cost. This was made possible by taking advantage of a serially manufactured An-2R agricultural support aircraft equipped with standard agricultural aircraft equipment and by adapting the former in a way which allowed mounting the A-25 jet engine in it. Besides mounting the engine and the starting system, the cowling, the air intake, the fuel and fire safety system, the rear of the fuselage had to be completely rebuilt to allow the emission of jet gases from the engine, to raise the tail plane and to introduce a twin vertical tail unit. The rear landing gear had to be redesigned and shifted and a new solution had to be found for a way of entering the cockpit. Although these modifications were considerable, they applied only to one part of the aircraft.

The following parts were retained unchanged: the entire wing cellule of the biplane together with the collaborating portion of the fuselage, the main landing gear, the crew's cockpit with all equipment and the main control elements. The entire power unit, i.e. the ASz-62IR piston engine with the AW-2 airscrew was also retained intact. This shortened design and workshop work, however, above all, facilitated and shortened formalities connected with obtaining permission to operate the aircraft in flight.

The experimental aircraft named LALA-1 (flying laboratory-1), obtained in this manner allowed conducting studies in the following spheres:

- action of exhaust gas stream from jet engine on transverse uniformity of band of chemicals and on cultivated plants (during low flight).

- resistance of jet engine to effects resulting from pollution by chemicals and dusty atmosphere during service flight and ground manoeuvres (taxiing, take-off, landing).

- effect resulting from use of jet propulsion on piloting techniques during agricultural aircraft manoeuvres.

- effect of jet engine noise on working conditions of crew and ground service personnel.

Retention of a piston engine on the aircraft (besides the added jet engine) also allowed to compare directly the characteristics of an agricultural support aircraft with two different types of propulsion--piston-airscrew and jet propulsion.

The decision to build a flying laboratory was made in June 1971. Design work took about 6 months, however implementation activities were executed simultaneously. The test flight of the aircraft, first only with an operating piston engine, took place on 10 February 1972. The second actual test flight with both operating engines took place on 26 April of the same year, i.e. 10 months after work began on the project, which ought to be considered an engineering and organizational success.

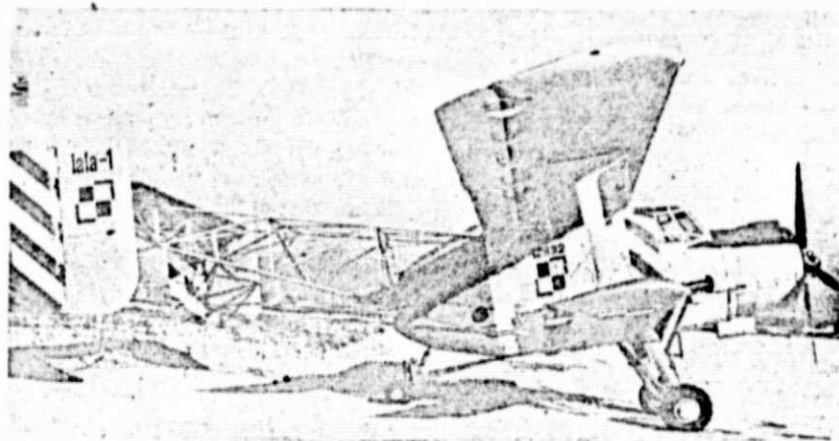
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Currently the flying laboratory is continuing the broadly conceived agroengineering research. The originally proposed program was expanded to an investigation of new unconventional systems of agricultural aircraft equipment. The effort invested in elaborating and building the aircraft is yielding measurable advantages. At the same time, the flight characteristics of an aircraft with a rarely encountered mixed power plant and the results of conducted agricultural support aircraft investigations are unusually interesting topics deserving extensive separate elaboration. The purpose of this article is a brief presentation of the most interesting technical problems which occurred during the design and building of the aircraft.

Rear Part of Fuselage

In principle, the design of the front of the fuselage was retained in the modified aircraft. The rear had to be removed because of the necessity of mounting a jet engine in it and ensuring the exhaust of jet gases to the rear. Hence, it became necessary to enclose the remaining front part of the fuselage and to add a structure replacing the rear which was cut off in order to transfer forces from the tail unit and rear landing gear. The fuselage was cut off closely behind frame 10, hence in the vicinity of the trailing edge of the upper airfoil. A strong 10A frame reinforcing the cutout was built-in in the cut place. The substitute structure was realized in the form of two frameworks--a longer framework, reinforcing the tail unit and a shorter framework supporting the jet engine and rear landing gear.

Due to the presence of the engine and the gas exhaust, neither of the mentioned frameworks could be built as a independent rigid unit. Consequently, the job of enclosing the fuselage is realized by frame 10A, which is made in the form of a very rigid thick (1.5 mm) duralumin plate, framed both on the periphery and the interior rim of the cutout by angles extruded from duralumin whose dimensions are 30 x 30 x 3. In addition, the corners of the frame are reinforced with cover plates and the wall with riveted angles. The dimensions of the cutout in the frame were selected so that the tank with chemicals located in the fuselage can be removed or inserted through the cutout should its replacement or disassembly become necessary.



1. Visible: three-bay rear framework, elevated tail unit, cowlings of jet engine, rear landing gear and lateral air intake. Vertical tail unit plates are made from halves of tail plane which was cut off.

Four fastening ferrules of the rear frameworks were mounted on the perimeter of frame 10A. These ferrules are made from

steel 30 HGSA in the form of mountings with ports whose axes are parallel to the axis of the aircraft. They are equipped with fins which distribute the forces concentrated on the wall of the frame and on the skin of the fuselage. For better transfer of forces in the vicinity of each ferrule, the skin was reinforced with a large cover plate and an internal top-hat section, extending along the fuselage generatrix up to frame 8. The rear framework, which is constructed from steel 30 HGSA pipes, consists of four longerons reinforced with cross elements in the planes of lateral walls and in the plane of the upper wall which are supported by lateral struts. The lower wall of the framework had to be left open (without cross elements) since the jet of exhaust gases from the engine passes through it.

On the basis of weight analysis, the framework which was elaborated was a three bay framework. Increasing the number of bays from two to three reduced the weight by about 15%. To facilitate workmanship, the framework was subdivided from the production engineering standpoint. The framework consists of four flat subassemblies made using welding: two lateral walls and two frames--struts in the shape of an inverted letter K. The remaining elements are slack bars (6 pieces) criss-crossing the upper wall of the framework. To avoid clearances, the framework subassemblies are connected to each other with fitted double cut bolts. The rear framework is not rigid in torsion and it only acquires this rigidity after it is coupled at four points to the rigid fuselage. As was already mentioned, the second shorter framework is used to support the shock absorber in the rear landing gear and the struts of the rear part of the jet engine. It is made in the form of a pyramid welded from pipes having a trapezoidal base with apex turned upside down which is fastened to the lower fuselage joints at two points and propped up by two struts to the upper joints.

In this manner, both frameworks are connected to each other and to the fuselage at four joints determined by the ferrules which were described above. The frameworks are connected to each other by cut bolts (double cut bolts) and with the fuselage by pretensioned bolts operating exclusively on tension. In order to eliminate shearing and bending stresses, the bolts have a rather large clearance relative to the sleeve of the ferrule and the component forces acting in the plane of the frame are transferred through spherical projections protruding from the airframe joints which enter the conical joints of the fuselage ferrules. The bolts are made according to mandatory principles for bolts operated on tension, i.e. the diameter of the "working" part which takes up a greater part of the bolt's length is smaller than the diameter of the bolt's core and the surface of the working part is smoothed to eliminate the effect of a dent. Initially, the bolts were made with heads and were to be inserted in the framework and fuselage ferrules from the rear, which was to be followed by tightening with nuts from the interior side of the fuselage. However, it became evident that this activity could not be carried out due to lack of suitable access and room for the tool (wrench). Tightening of the bolt from the side of the head was not considered because of possible twisting of the bolt.

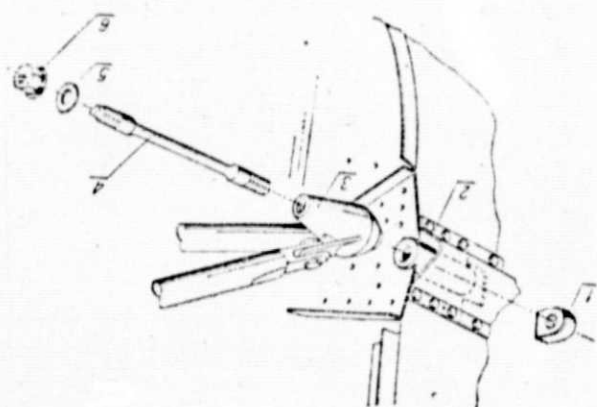


Fig. 2. Framework-fuselage connection, lower left joint. 1 - anchoring nut; 2 - fuselage ferrule; 3 - framework joint; 4 - nut; 5 - collar; 6 - pretensioned nut.

This problem was solved by changing the design of the bolts which were threaded on both sides. At the same time, the shape of the nut was changed on the side of the fuselage so that it could not turn in its seating. The bolts were screwed into the nuts through the ferrules to the stop by turning a wrench behind a flattening made beyond the external thread. After the framework was mounted, the bolts were tightened by nuts screwed on the external thread protruding from the joints of the framework.

The next problem was to obtain initial strains for bolts having the appropriate magnitude implied by the condition that no slack occur on the ferrules up to the maximum (calculated) external loads applied to the framework. A method was selected which measured directly the strains using strain gauges glued on to the working surface of special measurement bolts. The nuts were tightened by a torque wrench until the required strains were obtained and the final magnitude of the torque was determined in this fashion. During final mounting the nuts only had to be tightened to the same magnitude of the torque under identical greasing conditions by the same wrench. The advantage of pretensioned bolts is the theoretically constant strain which exists in them regardless of changes in external loads. This was confirmed during tests in which loads were applied to the framework. The increment in tensile forces in the bolts measured by strain gauges represented only a fraction of the forces acting on the joints of ferrules which resulted from loads applied to the framework. The load test was carried out to verify the rigidity of the framework. It turned out that this rigidity was much higher than that envisioned by BCAR (abbreviation unknown) requirements, part K. This established the validity of the assumed design assumptions and confirmed the correctness of the calculations. A complete

static test could not be carried out since only one aircraft was built.

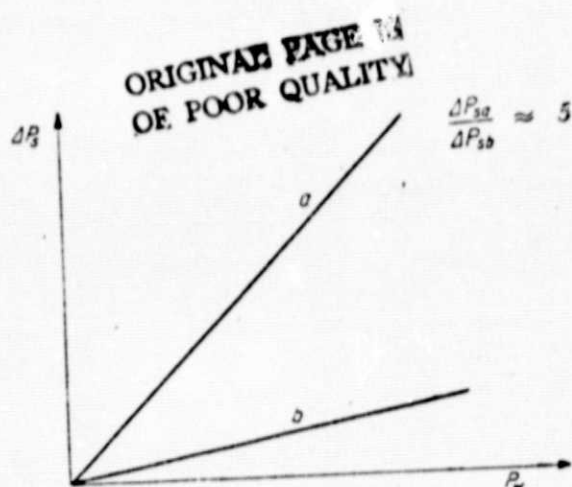


Fig. 3. Force increment ΔP_s in bolt vs. force applied to joint P_w obtained on the basis of strain gauge measurements. a. bolt without preliminary straining, b. pretensioned bolt.

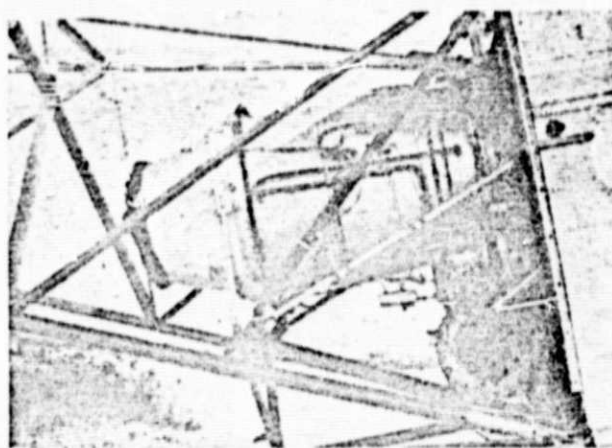


Fig. 4. Jet engine power plant. Photo shows: AI-25 engine, AI-9 starting engine, main pivot housing, supported by struts to rear and top and strut supporting rear of engine.

Control Surfaces

In conformity with the presumed maximal utilization of existing assemblies and structural elements, it was decided to use the tail plane from the modified A-2 aircraft in the LALA-1 aircraft. The tail arm was also retained. The latter was only raised to remove it from the jet of hot gases and also to obtain some similarity to the new aircraft. It is common knowledge that the control surfaces of the An-2 aircraft are mounted in cantilever fashion, namely they are attached at four points to the rear of the fuselage and supported from both sides by struts, each of which is connected at two points to the fuselage. In the LALA-1 aircraft the situation has been reversed--the control surfaces are attached to the framework by external (strut) ferrules and the center ferrules are supported by struts in the shape of the letter V. Flat triangular lattice elements are used to connect strut ferrules with the fuselage framework. These elements together with the mentioned struts (a small pyramid connecting the four center struts, and a rod connecting the lower points of all these elements) form a kind of transverse framework constituting a unit imparting greater rigidity to the tail plane.

Since mounting a central tail plane would be inconvenient, it was decided to use a twin tail plane in the form of plates on the edges. To avoid designing and making new elements, the two halves of the tail plane which was cut at rib 4 were used for this purpose, from which only the ends were utilized. A pipe outrigger with a support ferrule was mounted at rib 4 (end rib) of each half of the stabilizer. The plates obtained in this manner were attached to the ends of tail plane using the old strut ferrules to which suitable ferrules were added.

In addition, the lower part of the fins was supported by V-shaped struts whose vertices rested on lower points of the tail plane framework. Similar struts emanating from the same points were also supporting the ends of the tail plane at ferrule points at which the fins were mounted. In this manner the external framework imparted greater rigidity to the control surfaces and reinforced them. Such reinforcement was useful, since greater forces were expected on the control surfaces than in the An-2 aircraft due to, among other things, the presence of plates at the edges which increased the effective aspect ratio of the tail plane.

The control surface framework is also used for attaching the control surfaces to the rear framework of the fuselage. The frameworks are connected to each other by means of an articulated joint at lower points. Upper joints are equipped with screw connectors which are used for adjusting the setting angle of the tail plane.

To reduce aerodynamic drag of the framework, it was decided to fair some struts, especially those which were in a position transverse to the direction of flow. The fairing was made in the form of frontal and fillet cover plates glued to the pipes and veneered with glass fabric. The cover plates were made from frothed styrene foam in very simple metallic molds so that apart from glueing they did not require any manual working. Since the control surfaces of the An-2 aircraft are covered with cloth, there was the danger that they may be ignited by the hot exhaust gases from the jet engine when mounted on the LALA-1 aircraft. This hazard had to be eliminated. For this purpose, for the first time in the country, the skeleton of the control surfaces was covered with a noninflammable glass fabric and protected with polyester enamel.

Rear Landing Gear

Because the rear of the fuselage was cut off and replaced by an upward slanting framework, it became necessary to shift forward the point at which the rear landing gear was mounted and to completely rebuild the landing gear itself. The old ground angle of the aircraft was retained while selecting the new position of the rear landing gear axis. The position of the axis was selected approximately one half the distance between the axes of the main wheels and the axis of the old tail wheel (An-2 aircraft). This doubled the loads acting on the rear landing gear. For this reason, two An-2 aircraft tailwheels were used instead of one wheel. They were mounted on a common axis on both sides of a single fork seated on bearings in a housing permitting a complete 360° revolution of the fork and wheels about the approximately vertical axis of the housing (similarly as in the An-2 aircraft). The fork housing constitutes the rear joint of a drawn rocking arm welded from steel 30 HGSА, whose front joints are used for suspension on ferrules built in below the fuselage in the vicinity of frame 10A. The slanted suspended assembly is supported at the rear joint of the rocking arm by a single shock absorber whose upper point rests on the lower joint of the shorter framework described above. A ready oleo-pneumatic shock absorber from the main landing gear of the MD-12 aircraft was used. The latter, which was found in the remaining stock after discontinuation of this aircraft, required only minor modifications in adapting it for operations under new conditions. This reduced considerably design and production work. The fork of the wheel assembly, seated in rotary fashion in the housing, is centered in the rear position by a cam-roller device and locked by an air hoist whose journal falls into a hole in the flange of the fork axis. Both devices were adapted from the rear landing gear of the An-2 aircraft.

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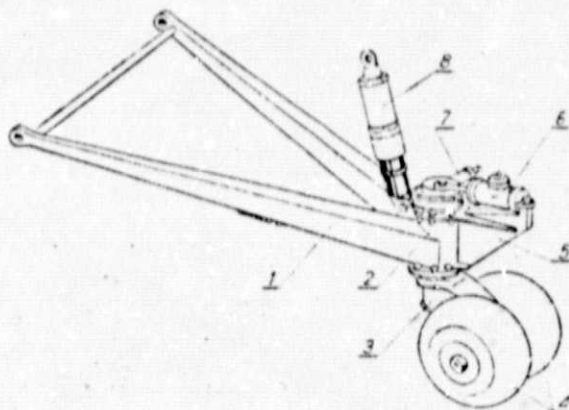


Fig. 5. Rear landing gear: 1. rocking arm, 2. fork housing, 3. fork, 4. wheels, 5. damper bracket, 6. shimmy damper, 7. locking hoist, 8. shock absorber.

While testing the rear landing gear on a drop hammer test bed, strong shimmy type vibrations were observed at rotational speeds of the drum corresponding to a taxiing speed of 40 km/h. The vibrations appeared when the fork was locked and unlocked. In the latter case, it was established that the vibrations are caused by an excessively large clearance on the locking journal. After the clearance was eliminated, the vibrations disappeared and did not reappear in the investigated range of taxiing speeds (up to 120 km/hour).

The elimination of vibrations while the fork was unlocked (for example, as a result of the pilot's oversight or a defect in the system) was a much more serious problem. The shimmy damper from the MD-12 aircraft, patterned after the solution used in LIF aircraft, which was used in the first testing stage turned out to be inadequate and it did increase the safe taxiing speed. The reason for this was probably the system transmitting the motion of the fork's journal to a set

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of plungers in the damper, which was too complicated and involved a large number of collaborating parts and clearances between them. Hence, it was decided to use another damper, this time one adapted from the TS-11 aircraft, in which the motion of the fork's journal is directly transmitted to the plunger of the damper in very rigid fashion. Application of this damper markedly improved the situation, i.e. the vibrations disappeared and the established safe taxiing speed both with a locked and unlocked fork was 120 km/hour. As part of further improvements, direct electric signalling of the position of the locking hoist was introduced (using microswitches controlled by the motion of the plunger proper). Both the locked position and completely unlocked position are being signalled.

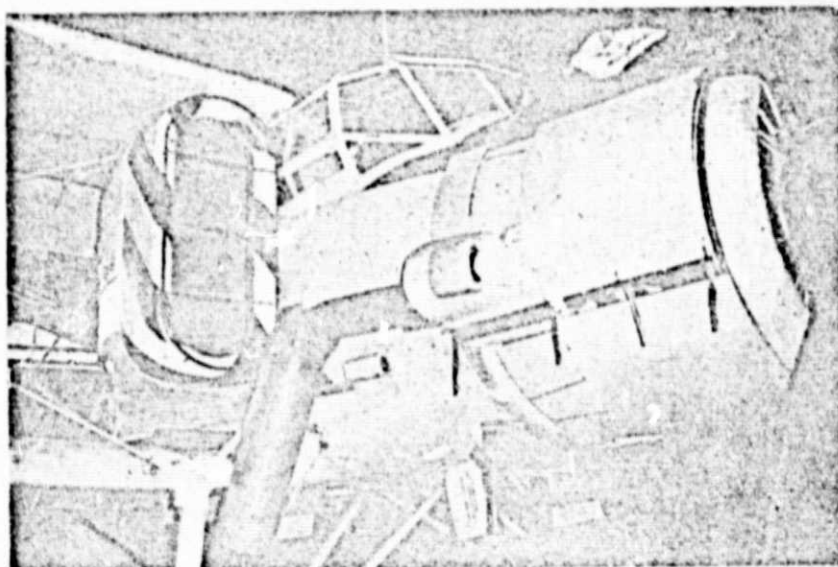


Fig. 6. Side air intake. Photo shows: dimensions of intake, rounded edges, protective screen and duct through which exhaust gases from ASa-62 engine are drawn off under the wing.

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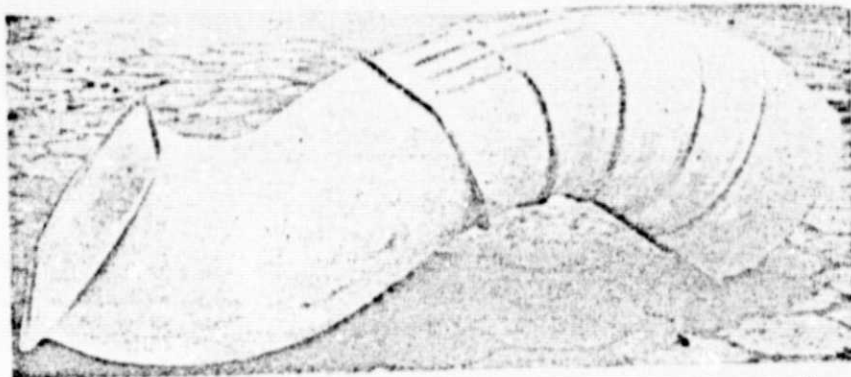


Fig. 7. Laminated AI-25 engine air delivery channel (variant 1). Bottom view. Photo shows "S-shaped" channel.

Power Plant

Mention was already made of the fact that the entire piston-airscrew power plant with the 1000 hp ASz-IR engine was adapted on the LALA-1 aircraft. An AI-25 by-pass turbojet engine with a maximum static thrust of 1500 kg was mounted as an additional power plant. Besides the mentioned engine, this power plant also comprises the AI-9 starting engine (constituting an air generator for pneumatic starting), a separate fuel system supplying both engines, a separate fire safety system and an air intake channel supplying the AI-25 engine.

The AI-25 engine is serially manufactured and used in operating type Yak-40 short-range passenger aircraft. The scheme used to mount the engine in the LALA-1 aircraft was identical with that used for the central engine in the Yak-40 aircraft. Two main journals pushed into seats of lateral joints in the front part of the engine take over the forces directed along the longitudinal (X) and vertical (Z) axis and

the moments with respect to these axes. Displacement of the engine along the journal axis is eliminated by means of a slanting strut mounted tangentially to the periphery of the front part of the engine, while rotation about the journal axis is thwarted by two struts supporting the rear lateral joints of the engine.

The AI-25 engine is mounted with respect to the aircraft so that its axis, which is parallel to the axis of the ASz-62 engine, is shifted by 500 mm upward and 200 mm to the right. The main journals are mounted in slidable fashion in steel housings fastened in the fuselage immediately before frame 10A. The flanges of the housings are connected by two struts with rear upper joints of the short framework located behind frame 10A (the rear struts of the engine rest on the same joints). In addition, the left longer housing is supported by a strut in the horizontal plane. To immobilize the main journals in the housings, bolts are passed through the former at the exhaust. The AI-9 starting engine is mounted laterally to the direction of flight behind frame 10A on the framework bracket welded from steel pipes. The air intake to the engine is located on the left side. The opening in the cowlings of the engines, which is protected by a screen, is located in this area. The exhaust of gases from the engine takes place on the right side through an exhaust pipe constituting an extension of the engine's nozzle. The AI-9 engine is connected via piping to the starting system on the AI-25 engine.

Both engines are enclosed together with the shorter rear framework by cowlings made from duralumin plates of which the two lateral ones are easily removed for inspection and service. The space around the engines is divided into fire zones, a separate zone for the AI-25 engine and a separate zone for the

AI-9 engine. The third fire zone is the interior of the second contour of the AI-25 engine. Each zone can be extinguished separately using a fire system on board. Obviously, the principal zone is the one around the AI-25 engine. The front of the engine is approximately located in the plane of frame 9. The main fire partition made from 1H18N9T sheet metal is mounted on this frame. Initially frame 10A was not shielded. However, before the first flight with an operating jet engine was performed, following a suggestion made by the commission which permitted the aircraft to be flown, the partition was supplemented with slanted 1H18N9T sheet metal which reduced the space around the engine fuselage region and protected the duralumin carrier structure of the fuselage together with frame 10A. In the region of engine cowlings the space around the engine was effectively reduced by using very thick double walls.

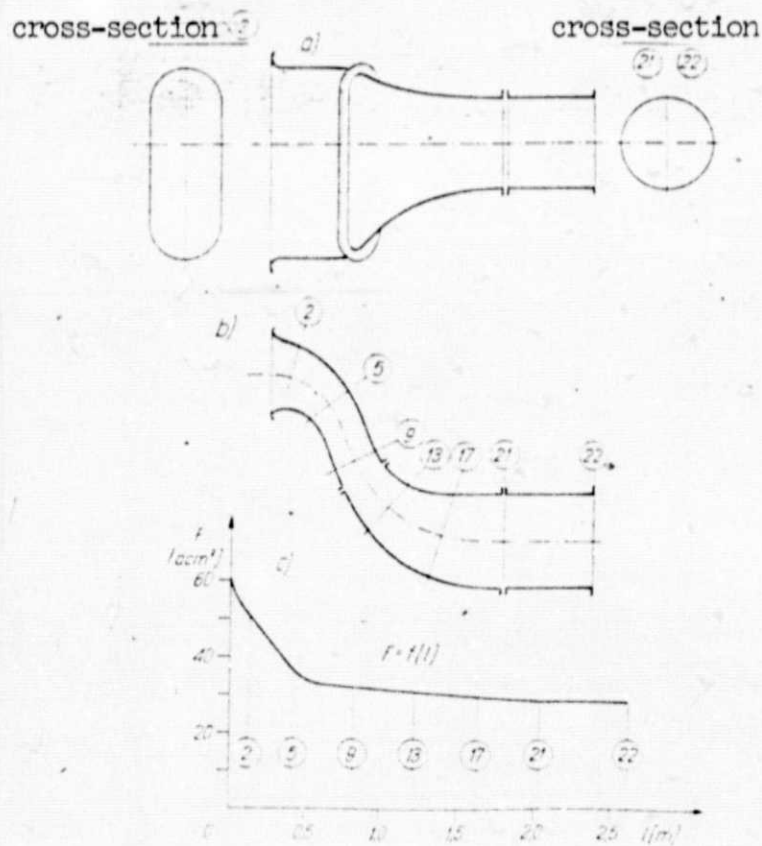


Fig. 8. Shape of AI-25 intake channel. A - side view, B - top view, C - developed view, F - channel cross-section.

The demarcation of a separate fire zone around the AI-9 engine, i.e. the isolation of the space of this engine from the space of the main engine presented a slight problem. Because of the small distance between both engines the use of a rigid partition was ruled out. After many tests a partition of the soft type was selected which was composed of two layers of soft asbestos tissue interspersed and lined with thin aluminum foil. A thin glass fabric was glued to the external layers of the foil to protect it from mechanical damage.

The "quilt" made in this manner withstood for five minutes during tests the action of a standard flame whose temperature was 1110°C (according to BCAR), while the temperature on the cold side did not increase for all practical purposes. Another problem connected with the AI-9 engine was the phenomenon of an improperly switched on fire signal after the AI-9 was turned off, which was difficult to control. The reason for this was the excessively rapid increase in the temperature of the engine (sensors which switch on the fire signal react to a temperature gradient exceeding $1^{\circ}\text{C}/\text{sec}$) after cooling is discontinued. The latter takes place by means of an external flow of air around the engine which is sucked in by gases leaving the nozzle of the engine (injection effect). Improved efficiency of the injector obtained by further advancing the edge of the exhaust pipe cooling jacket reduced the temperature around the engine during its operation; however, after the engine was turned off, the rise in the temperature gradient was even greater. An attempt was made to ensure also cooling of the AI-9 engine after the latter was turned off by mounting additional injector devices at the exhaust of the AI-25 engine. However, this did not produce the expected results, probably due to the low rate of the external flow from the engine. Finally, the "false fire" phenomenon was overcome by slipping over the sensors protective

jackets, which slightly increased the value of the temperature gradient causing the appearance of a signal.

Many important problems were brought forth during elaboration of the channel for the delivery of air to the AI-25 engine. The design had to take into consideration the high air requirements of the engine (44 kg/sec), as well as the necessity of obtaining high engine work rates and consequently small losses at the intake at the low velocities envisioned during operation of the aircraft. At the same time, the position of the air intake and the basic shape of the channel had to take into account the presence of elements in the supporting structure of the fuselage and the equipment in its interior (tank for chemicals and crew's cockpit). The air intake with gently rounded edges was placed on the right side of the fuselage at the height of the cockpit. Almost immediately behind the intake the channel bends sharply and enters the interior of the fuselage through a hole cut out in the skin between frames 5 (rear wall of cockpit) and 6 (front frame of spar). The next bend, already inside the fuselage, aims the channel axis onto the axis of the engine. The air intake is oval-shaped. At the place where it passes through the side of the fuselage, and consequently at the place with the greatest curvature, the channel is highly flattened which is necessary because of the small space between frames 5 and 6. The latter had to be left intact because of structural strength considerations. However, this flattening is advantageous since it constitutes a natural "fence" preventing the occurrence of cavitation phenomena on the interior wall of the bent channel caused by displacement of air masses under the action of inertial forces. Only inside the fuselage the cross-section of the channel becomes gradually circular. The last section of the channel is perfectly

cylindrical over a length equal to the diameter. The taper of the channel has an important effect on its efficiency. The channel tapers gently over the entire length (except the last sector) and its cross-section changes linearly. A uniform pressure drop along the walls of the channel during flow was obtained in this manner. A channel having this shape turned out to be very appropriate in operation. The surging phenomenon was never ascertained under any operating conditions of the engine which should be viewed as a success considering the rather complicated shape of the channel.

Because of its complex shape, the channel was made from a glass laminate. ST-31 glass fabric and Epidian 53 resin were used. In the first version the walls of the channel were made from several layers of fabric saturated with resin and reinforced outside with braces having a triangular cross-section made from a laminate filled with styrene foam. The braces were glued on to the finished shell. This channel structure turned out to be weak, resulting, in turn, in damage to the channel caused by the negative pressure prevailing inside the channel while the operation of the engine was tested on the ground.

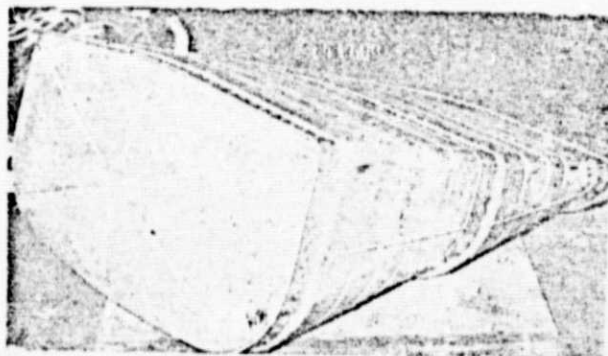


Fig. 9. Oil tank, capacity 400 l.

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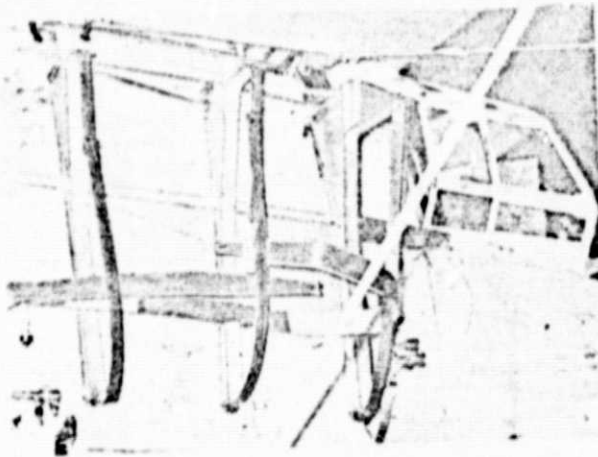


Fig. 10. Oil tank mounting on right side of fuselage with system of fastening straps.

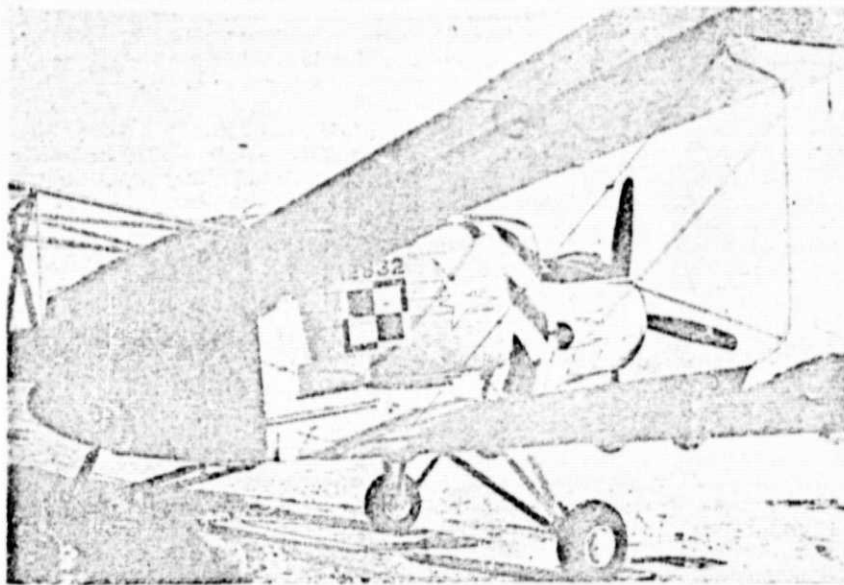


Fig. 11. Oil tank enclosure on right side of fuselage behind air intake inlet.

A layered structure was selected for the second channel version which consisted of two triple layers of laminate separated by a Polocel (foamed polyvinylchloride) 15 mm thick interlayer on cambered surfaces, and a 30 mm thick interlayer on developable surfaces. After it was made, the channel was subjected to tests on a test bench whose purpose was to determine, among other things, the distribution of pressures. Next, a static test was performed in which the channel was subjected to loads from the negative pressure generated inside and also from the external mechanical system. The results of both tests were favorable and permission was granted to use the tested element in normal operations.

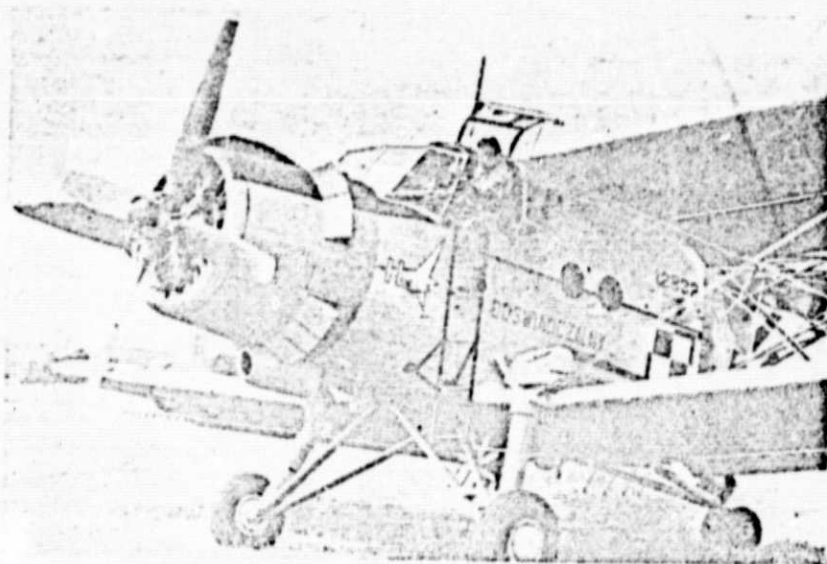


Fig. 12. Exit from cockpit. Photo shows: open doors of cockpit, stationary ladder and railing along fuselage.

Close attention was also given to conditions prevailing in the vicinity of the air intake, among others, to the interaction of the air intake and airscrew. Measurements made

while operating the jet engine showed only minimal disturbances in the velocity field in the plane of the airscrew (within measurement error).

Operating the airscrew at full thrust also did not cause any noticeable disturbance in the operation of the jet engine.

Since the gas exhaust from the exhaust manifold of the ASz-62 engine was located opposite to the jet engine air intake, it became necessary to direct the exhaust gases beyond the range of the air intake. This was achieved by using a slanted metal sheet duct, whose top end enveloped the terminal of the exhaust manifold which was bent downward, and whose bottom end protruded under the lower wing. During first tests of the jet engine on the ground, it became evident that the negative pressure in the vicinity of the air intake induces a flow in the duct of the exhaust manifold which is opposite from the intended one, i.e. from bottom to top. However, after operating the ASz-2 engine, it was ascertained that the injector effect of the exhaust gas jet from the exhaust manifold is dominant and that the direction of flow in the slanted channel is correct, i.e. from top to bottom.

It was already mentioned that the AI-25 and AI-9 turbine engines are supplied with fuel (oil) from a separate fuel system. The main element in the system is a tank containing 400 liters fuel. The tank is mounted inside the fuselage from the right side below the fairing constituting an extension of the air intake. The fuel filler of the tank is located in the upper fairing of the right wing. The shape of the tank is determined by the place assigned for its installation. Hence,

it is flat and high, which gives rise to great loads especially on the bottom part, caused by hydrostatic pressure. These loads have a bearing on the required rigidity and strength of the tank. The design and production engineering of the tank were elaborated on the basis of results of resonance and strength tests and vibration resistance tests conducted on a vibration stand, while the vibration parameters were determined on the basis of measurements conducted aboard the aircraft. After initial failures and a final elaboration of the structure, two identical copies of the tank were made. One of these copies passed successfully the long-term vibration resistance test, on the basis of which permission was granted to mount and operate the second identical copy aboard the aircraft.

The great height of the tank caused difficulties in finding a solution for the system measuring the content of the tank, since it precluded the use of a standard potentiometric floating-lever fuel gauge. However, a simple and efficient solution was found in the form of a contactron fuel gauge. The fuel gauge float with built-in permanent magnets moves on a pipe along which the contactrons are spaced out. In the beginning only four contactrons were used which switched on sequentially four lamps on a simplified indicator in the cockpit indicating a $1/4$, $1/2$, $3/4$ and completely filled tank. However, such a large graduation of readings turned out to be inconvenient in operation, especially in the final fuel depletion stage. In practice, the lit "1/4 fuel tank" lamp was a signal for terminating the flight since the pilot did not know exactly how much fuel actually remained in the tank. In the improved version, the number of contactrons in the fuel gauge pipe (which are switched on in series by resistors) was increased to 40. At the present time, the indicator system is a four coil d.c. current quotient meter with a 290° pointer deflection angle. The discrimination

capacity of the fuel gauge is 10 liters (the pointer moves in 10-liter jumps).

Crew's Cockpit

Cutting the rear of the fuselage and mounting the jet engine together with the intake channel prevented the crew from entering the cockpit through the hold. Another way of entering the cockpit had to be found. For this purpose, the lateral part of the glazing on the left side of the cockpit was cut out and mounted on hinges along the upper edge. The doors made in this manner open up upward and allow a relatively convenient entrance into the cockpit. To facilitate entry, a stationary ladder made from steel pipes was mounted on the side of the fuselage. In addition, several handle grips were placed inside and outside the cockpit to facilitate entry and exit. Close attention was given to the safety of the crew. The seats of both pilots were equipped with safety belts which were not used in the serially manufactured An-2 aircraft. In case of a crash, the doors of the cockpit can be flung open (independently of the roof of the cockpit which can be flung open as in all An-2 aircraft). If the aircraft must be abandoned in flight, the pilot flings open the door and steps onto the ladder from which he moves over to the walk near the root of the lower airfoil. Holding on to the pipe hand-rail mounted along the fuselage, the pilot moves to the trailing edge of the wing from where he jumps. During crash aircraft abandonment tests conducted on the ground, the approximate time from the instant the pilot started leaving the cockpit until the jump was about 4 seconds.